Applications of Image Registration

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Abstract- This paper aims to present a survey of different applications of image registration technique. Image registration is a pre-processing step for different applications. It consists of mainly four steps: feature detection, feature matching, transformation model estimation and image resampling and transformation. Image registration has wide applications in remote sensing, in medicine and agriculture using different methods and techniques, which have been presented in this paper.

Keywords-image registration, feature based method, area based method, remote sensing, biomedical and agriculture.

1. Introduction

The main task of image registration is to align the two or more images acquired at different time, from different sensors and from different viewpoints. It is the process of transforming the different sets of data into one co-ordinate system [1]. Registration is required in remote sensing, in medicine and in computer vision [2]. Image registration mainly consists of four steps: 1. Feature detection 2. Feature Matching 3. Transformation model estimation 4. Image resampling and transformation [2, 3, 4].The objective of registration is to find an optimal spatial and intensity transformation such that images become aligned into the same coordinate frame. Mathematically, the problem of registering an input image I(x,y) to a reference image R(x,y) can be expressed as follows[4],[5]:

$$R(x, y) = g\,(I(T(x,y))) \qquad (1)$$

whereT indicates a transformation function which maps two spatial coordinates, x and y, to the new spatial coordinates, xand y:

$$(x, y) = T(x,y) \qquad (2)$$

andg denotes a one-dimensional intensity or radiometric interpolation function.

2. Need of Image Registration

Image registration is very much essential to find the optimal transformation that best aligns the structures of interest in the input images [6]. The main task of image registration is to determine the amount of translation and amount of rotation that has sensed image w.r.t reference image [7].

3. Applications of Image Registration

Image registration has wide applications in remote sensing, biomedical and agriculture which are explained as follows:

3.1 Remote Sensing Applications

H.-m.Chen et al. [8] in 2010, introduced a mutual information-based image registration for remote sensing data. They had implemented their proposed method through joint histogram estimation using various interpolation algorithms such as nearest neighbour, linear, cubic convolution and partial volume interpolation. They had investigated mutual-information based image registration technique for multi-sensors and multi resolution images. It had been concluded from the experimental results that the nearest neighbour interpolation performed better than the linear or cubic convolution interpolation.

P.Schwind et al. [4] in 2010, had presented applicability of SIFT (Scale Invariant Feature Transform) operator to geometric SAR (Synthetic Aperture Radar) image registration. The proposed method had following two modifications which are as follows:
1) Skipping of first scale-space octave (SIFT-OCT), which reduced the numbers of key point detections and processing time.
2) Infinite Symmetric exponential filter, which involve a smoothing filter to reduce the speckle or noise.
For the applicability of SIFT operator to SAR image registration, datasets had been tested.

Z. Mao et al. [5] in 2010, had presented an automatic registration of SeaWiFS (Sea-Viewing Wide Field-of-view Sensor and AVHRR (Advanced very High Resolution Radiometer) imagery.
The whole process of image registration typically consists of five steps which are as follows:
(1) Points in the first image are selected for candidate GCPs (Ground Control Points).
(2) Corresponding points in the second image are identified by a suitable point-matching technique. (3) The correctness of GCPs is checked by a reliable decision rule.
(4) The coordinates of GCPs are used to calculate coefficients of a mapping function.
(5) The mapping function is used to register spatially the two images.
The GCPs like line, intersections, line segments, oil and gas pads etc. had been detected for coastline, which is an edge in a satellite image using various edge detection technique like Roberts, sobel and Prewitt. Among these Robert's operator is suitable for extracting the coastline from a pre-processed satellite image. They had introduced a combined technique of correlation and relaxation (CR) of pattern matching for searching consistent matching points.

Wenjian Ni et al. [9] in 2011, had presented a method for the registration of multiview range images acquired in forest areas using a terrestrial laser scanner. Range images acquired within the forests, had been used to make detailed measurements of individual trees, including maps of stem position and tree dimensions. The registration process of two images is to transform the co-ordinates of points in one image into that of the other. They had proposed a method for registration of multi-view range images acquired in forest areas using an inclinometer together with positions of tree trunks and ground surface information.
The range images acquired by prone scanners were first matched with the one acquired by a standing scanner at same station. After that the range images acquired by standing scanners were used for registration between stations.

H. Gonçalves et al. [10] in 2012, had presented a correlation and Hough transform based image registration method. Correlation is able to geometrically align the two images at pixel level but unable to achieve is at sub pixel level. If the images are divided into tiles and centre of each tile is used as a point, the conjugation of all points may lead to a geometric correction at the sub pixel level.

Li Wang et al. [11] in 2012, had presented a robust multisource image automatic registration system based on the SIFT descriptor.
Jie Jiang et al. [12] in 2013, had presented Shape registration for remote-sensing images with background variation. For the remote sensing images, the texture is damaged by background variance becomes unreliable for all region-based descriptors. They had implemented their methodology using level line descriptor (LLD)

and test the performance of this improved descriptor using residual error and computation cost as a quality measure to judge the matches found.

M.Ravanbakhsh et al. [14] in 2013, had presented a comparative study of Digital Elevation Models (DEM) registration approaches. For the registration of two DEMs, there should be proper surface to surface matching between the horizontal and vertical offsets. The horizontal and vertical offset between overlapping DEMs can be determined either separately or simultaneously. There are two types of approaches for registration one is 3-D and other is 2.5 D.
In 2.5 D approaches, horizontal offsets are first estimated through the use of an image similarity method. This is followed by a determination of weighted means to compute vertical offset. The three similarity metrices, used are cross correlation function, mutual information and gradient based mutual information.
In 3-D approaches, the three translations in planimetry and height (x, y and z directions) are estimated in one computational process. The slope based approach and Iterative Closest Point (ICP) algorithm is used under this approach. The main purpose of ICP algorithm is to find the different transformation parameters and for which the error metric defined via Euclidian distance between the corresponding surface points, is minimum.

QizhiXu et al. [15] in 2014, had presented improved SIFT (Scale Invariant Feature Transform match for optical satellite images registration by size classification of blob-like structures. They had presented two drawbacks of previous used SIFT method which are as follows:
1. SIFT gives high rate false match of key points.
2. There is heavy burden on computation.
The main advantage of the proposed method is that the false match rate and computation cost are significantly reduced.The proposed method has two modification from the previous SIFT method, which are as follows:
1. Scale normalization, which is performed before the step of Scale-space extrema detection, results in improve rate of matching.
2. Size classification, which is performed before the step of key-point matching.

Liang Cheng et al. [16] in 2014, had presented automatic registration of Coastal Remotely SensedImagery by Affine Invariant Feature Matchingwith Shoreline Constraint. They had implemented the methods in two steps, which are as follows:
1. High quality Affine Invariant feature matching.
2. Affine Invariant feature matching filtering with shoreline constraint.
They had compared their filtering technique with standard AIFM and concluded that their proposed method has much higher correct matching. The RANSAC (Random Sample consensus) threshold had determined, which also improved the matching results.

L.J. Yang et al. [17] in 2014, had proposed a new affine invariant feature extraction method for SAR (Synthetic Aperture Radar) registration. Due to speckle noise and deformable objects, registration task is difficult. The proposed method had divided into 3 steps:
1. A multi-scale isotropic matched filter (MIMF) operator is modified to detect salient features.
2. A multi-resolution search strategy is adopted for eliminating unstable features and affine invariance is achieved by an affine adaptation process.
3. Finally A point set registration method basis on Coherent Point Drift (CPD) is applied to SAR image registration problem.

TanakornSritarapiapat et al. [18] in 2014, had presented fusion and registration of THEOS (Thailand Earth Observation Satellite) multispectral and panchromatic images. According to author, Image fusion algorithms can be classified in 3 categories:
1. Feature based method, in which input image is segmented using various segmentation techniques.
2. Transform based method, which converts the input image into common transform domain.

3. Pixel based method, in which a pixel in fused image is determined from a set of pixels by the input sources. The quality of fixed images are degraded when the multispectral and panchromatic images were not perfectly registered. So, they developed a Maximum a posteriori (MAP) estimator to produce a high resolution multispectral image. For the experiments, they had taken different scenes from several parts (urban, drought, agriculture, coastal) of Thailand.

Bisheng Yang et al. [19] in 2015, had proposed an Automatic registration of UAV (Unmanned-Aerial Vehicles)-borne sequent images and LiDAR (Light Detection and ranging images) data. The proposed method is divided into 3 steps:

1. Extracting building outlines from LiDAR data and key images and establishing correspondences to estimate the key frame-image exterior Orientation parameters (EOPs) in the LIDAR reference frame.
2. Recovering the EOPs of the sequent images in the photogrammetric co-ordinate system using SFM technique and estimating transformation between LiDARrefence frame and the photogrammetric co-ordinate system by means of EOPs of key frame images using a voting procedure to achieve a coarse registration.
3. Refining the coarse registration by registering the 3-D points generated from the sequent images and the LiDAR data by means of ICP (Iterative Closest Point) using the coarse registration.

3.2 Biomedical Applications

Juan Du et al. [20] in 2007, proposed an intensity based robust similarity technique to match the multimodal brain images. In the presence of outliers or noise the registered image would be affected negatively. Therefore for the better results the noise should be reduced. The authors had introduced a similarity metric known as Double Directional Partitioned Intensity Uniformity (DRPIU), which is combination of forward and inverse transform. Global optimization simulation had been applied to avoid the local minima. For increasing the speed of optimization, multiresolution technique is combined with Powell method. At the end, they had compared their results of proposed method with PIU (Partitioned Intensity Uniformity) method and mutual-information (MI) method.

Francisco P.M. Oliveira et al. [21] in 2010, proposed registration of pedobarographic image data in the frequency domain. The main implementation issue is that the transformation from rectangular co-ordinates to log polar coordinates does not distribute the images pixel uniformly.
It had been concluded from the experimental results that the proposed method performed good alignments for inter-subject registration, even when the foot shapes were considerably different.

Jiing-Yin-Lai et al. [22] in 2010, presented a new registration method for three dimensional knee neathrosis model using two of X-ray images. They had proposed a model based method in which CAD model is acquired by reverse engineering. The CAD model is then converted into 2-Dimensional (2-D) image by rendering technique. The compatibility of X-ray image and image of CAD model had been investigated. For the verification of robustness and accuracy of the proposed method four different tests had been conducted as:
(1) Accuracy of the rotational axes: the tests are conducted by repeatedly selecting points from the same image to evaluate the rotational axes and checking the repeatability and accuracy of the results.
(2) Accuracy of the positioning points: similar tests are performed to check the repeatability and accuracy of the positioning points evaluated.
(3) Accuracy of the contour evaluated from the CAD image: implemented to check the accuracy of the error comparison algorithm between the contours of the X-ray image and the CAD image.
(4) Accuracy of the registration: implemented to check the accuracy of the overall registration algorithm by comparing the six position and orientation parameters of the prediction with those of the actual condition.
The extensive computer simulation and vitro experiments using real X-ray images had been implemented to investigate the feasibility of the proposed registration method.
They had presented the two limitations of vitro experiments which are as follows:

1) It does not consider the effect of image quality.
2) The real pose of two mounted components is unknown and therefore accuracy of registration result could not verified.

Wen-Chen Lin et al. [23] in 2010, had presented an approach to automatic blood vessel image registration of microcirculation for blood flow analysis on nude mice. They performed microscopic system analysis without fluorescent labelling to provide precise and continuous quantitative data of blood flow rate in individual micro vessels of nude mice. They had implemented the registration method based on Powell's optimisation search method.

Tadashi Araki et al. [24] in 2015, had presented a comparative approach of four different image registration techniques for quantitative assessment of coronary artery calcium lesions using intra vascular ultrasound. The four registration methods are:

1. Rigid, which preserves the distance between two points and angles made by the points of the model.
2. Affine, which involves reflection and shear mapping. It can model global stretching and skewing.
3. B-splines, which provide suitable alternative to perform deformable image registration.
4. Demons, uses a classical optimization scheme to solve a deformable image registration.

And five set of calcium lesion quantification parameters are:

1. The mean lesion length
2. Mean lesion distance from catheter
3. Mean lesion arc
4. Mean lesion span
5. Mean lesion area
6. Normalised volume.

The comparison of different registration technique had been done using similarity measure of the lesion via overlap ratio, structural similarity index and mean structural similarity index.

3.3 Infrared Physics

Chieh-Li Chen [25] in 2015, had presented Infrared thermal facial image sequence registration analysis and verification. They had determined the registration parameters for infrared thermal facial images by Genetic Algorithm and create a fixed image for infrared thermal facial image through image pre-processing and edge localization. The image registration for the proposed method is divided into two stages:

1. Rough adjustment stage, which involves rotation and translation adjustment.
2. Minor adjustment stage, which involve scale and shear to enhance the effectiveness of registration.

3.4 Agriculture Application

Li Mingxi et al. [26] in 2010, proposed fusion algorithm for multisensory images based on PCA (Principal Component Analysis) and lifting wavelet transformation.
The steps for proposed algorithm is as follows:

1. PCA transformation is carried out on the matched visual image.
2. The first principal component of visual image and infrared images are merged using lifting wavelet.
3. The fusion result replaces for the first principal component of visual image.
4. Finally, the fusion image is obtained by using inverse PCA transformation.

For experiments, 20 visual images and near infrared images of an apple tree had been taken. The different parameters like average gradient, standard deviation, entropy, correlation coefficient had been analysed.

4. Conclusion and Future Scope

It has been concluded that image registration is an essential pre-processing step for any application like remote sensing, biomedical, biomechanics, physics and agriculture. Future work will be done on use of image registration in electronics application.

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